



**EDITOR**

**ERRY YULIAN TRIBLAS ADESTA**

## **HIGH SPEED CUTTING**

**An Approach towards Improved Machining Performance**



**Manufacturing and Materials Department**

Kulliyyah of Engineering  
International Islamic University Malaysia

2011

# **HIGH SPEED CUTTING**

An Approach towards Improved Machining Performance

## **EDITORS**

ERRY YULIAN TRIBLAS ADESTA

AMIR AKRAMIN SHAFIE

AGUS GETER EDY SUTJIPTO

WAN AHMAD YUSMAWIZA



**IIUM Press**

Published by:  
IIUM Press  
International Islamic University Malaysia

First Edition, 2011  
©IIUM Press, IIUM

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without any prior written permission of the publisher.

Perpustakaan Negara Malaysia

Cataloguing-in-Publication Data

Erry Yulian Tribilas Adesta, Amir Akramin shafie, Agus Geter Edy Sutjipto & Wan Ahmad Yusmawiza: High Speed cutting An Approach towards Improved Machining Performance

ISBN: 978-967-418-023-2

Member of Majlis Penerbitan Ilmiah Malaysia – MAPIM  
(Malaysian Scholarly Publishing Council)

Printed by :  
**IIUM PRINTING SDN.BHD.**  
No. 1, Jalan Industri Batu Caves 1/3  
Taman Perindustrian Batu Caves  
Batu Caves Centre Point  
68100 Batu Caves  
Selangor Darul Ehsan  
Tel: +603-6188 1542 / 44 / 45 Fax: +603-6188 1543  
EMAIL: iiumprinting@yahoo.com

# CONTENTS

## Preface

---

### PART I: KEY ENABLERS FOR HIGH SPEED CUTTING

---

## Chapter One – New Tool Life Models in Turning Hardened Steel AISI 4340 under High Cutting Speed

Erry Yulian Triblas Adesta<sup>1</sup> and Muataz Al Hazza<sup>2</sup>  
 1, 2. Faculty of Engineering – International Islamic University Malaysia  
 ✉ : eadesta@iium.edu.my / ✉ : mutaz\_hazaa@yahoo.com

---

1.1. Introduction.....	3
1.2. Experimental Work.....	4
1.3. Box-Behnken Design .....	5
1.4. Artificial Intelligent Model .....	10
1.5. Tool life models validation .....	12
1.6. Conclusion .....	14

## References

## Chapter Two – High Speed End Milling in Mould and Die Making

Mohammad Yuhan Suprianto<sup>1</sup> and Erry Yulian Triblas Adesta<sup>2</sup>  
 1, 2. Faculty of Engineering – International Islamic University Malaysia  
 ✉ : yuhan.suprianto@gmail.com / ✉ : eadesta@iium.edu.my

---

2.1 Introduction.....	17
2.2 The Advantages and Disadvantages of High Speed Machining .....	18
2.3 High Speed Milling Characteristics .....	23
2.4 High Speed Hard Milling .....	25
2.5 Limitations .....	26
2.6 Conclusion .....	27

## References

## Chapter Three – Development of Empirical Models for Surface Roughness during High Speed Turning for Hard Materials using Box-Behnken Design

Mohammad Yuhan Suprianto<sup>1</sup> and Erry Yulian Triblas Adesta<sup>2</sup>  
 1, 2. Faculty of Engineering – International Islamic University Malaysia  
 ✉ : yuhan.suprianto@gmail.com / ✉ : eadesta@iium.edu.my

3.1	Introduction.....	31
3.2	Box-Behnken Design .....	32
3.3	Experimental Design .....	34
3.4	Result and Discussion .....	36
3.5	Conclusion .....	38

### References

---

## PART II: MOVING TOWARDS HIGH SPEED CUTTING

---

## Chapter Four – Surface Roughness Prediction Model of Hardened AISI H13 in High Speed End Milling Operation

Afifah Mohd Ali<sup>1</sup> and Muhammad Riza<sup>2</sup>  
 1,2, Kuliyah of Engineering, International Islamic University Malaysia  
 ✉ : sakisakura@gmail.com / ✉ : muhammadriza@yahoo.com

4.1	Introduction .....	41
4.2	Concept of High Speed Machining (HSM).....	42
4.3	Advantages of HSM .....	43
4.4	Prediction of Surface Roughness Modelling In HSM .....	44
4.4.1	Approaches in Designing the Prediction of Surface Roughness .....	44
4.4.2	Response Surface Methodology (RSM) .....	45
4.5	Experimental Setup .....	46
4.5.1	Design of Experiments .....	46
4.5.2	Workpiece Materials .....	47
4.5.3	Cutting Tools .....	48
4.5.4	Workpiece Measurement .....	48

4.6 Results and Analysis .....	49
4.6.1 Surface Roughness Prediction Model .....	49
4.6.2 Sequential Model Sum of Squares.....	49
4.6.3 Lack of Fit .....	50
4.6.4 Analysis of Variance (ANOVA) .....	51
4.6.5 Diagnose of the Statistical Properties of the Model .....	52
4.6.6 Surface Roughness Prediction Model Equation .....	52
4.6.7 Surface Roughness Prediction Model Graph .....	54
4.7 Conclusion .....	57

## References

## Chapter Five – Sample Preparation on Ceramics Composite for Cutting Tools in High Speed Machining

A.G.E. Sutjipto<sup>1</sup>, A. Kaderi<sup>2</sup>

1,2, Kuliyah of Engineering, International Islamic University Malaysia

✉ : agus@iium.edu.my

---

5.1 Introduction .....	61
5.2 Methodology .....	63
5.2.1 Materials .....	63
5.2.2 Experimental Procedures .....	64
5.2.2.1 Powder Preparation .....	64
5.2.2.2 Preparing the Green Body .....	65
5.2.2.3 From Green Body To Sintered Body .....	65
5.3 Results and Discussion .....	67
5.3.1 Sintered Body Image .....	67
5.3.1.1 Sintered for 2 hours at T = 1500 °C, P = 25 000 psi .....	67
5.3.1.2 Sintered for 4 hours at T = 1500 °C, P = 25 000 psi .....	69
5.3.2 Scanning Electron Microscopy Image .....	71
5.3.2.1 Powder Used .....	71
5.3.2.2 Sample HIPed both for 2 hours and 4 hours .....	73
5.3.3. Comparison with Theoretical Density .....	75
5.3.4. Microhardness Measurements .....	77

5.4 Conclusion .....	78
----------------------	----

## References

## Chapter Six – Influence of Backcutting Phenomena to Surface Roughness of Hardened AISI H13 during High Speed End Milling Process

Afifah Mohd Ali<sup>1</sup> and Erry Yulian Triblas Adesta<sup>2</sup>  
 Kuliyah of Engineering, International Islamic University Malaysia  
 ✉ : sakisakura@gmail.com / ✉ : eadesta@iiu.edu.my

---

6.1 Introduction .....	81
6.2 Concept of High Speed Machining .....	82
6.3 High Speed End Milling .....	82
6.4 Backcutting Phenomena .....	83
6.5 Experimental Setup .....	85
6.5.1 Design of Experiments.....	85
6.5.2 Workpiece Material .....	86
6.5.3 Cutting Tools .....	87
6.5.4 Surface Roughness Measurements .....	87
6.6 Influence of backcutting on surface roughness (Ra & Rt) .....	88
6.7 Conclusion .....	91

## References

## Chapter Seven –Experimental Investigations in High-Speed Hard Turning of AISI 4340 Steel Using Mixed Ceramic

Muataz Al Hazza<sup>1</sup> and Erry Yulian Triblas Adesta<sup>2</sup>  
 1, 2. Faculty of Engineering – International Islamic University Malaysia  
 ✉ : mutaz\_hazaa@yahoo.com /✉ : eadesta@iium.edu.my

7.1	Introduction .....	93
7.2	Experimental Design .....	94
7.2.1	Average of Surface Roughness Measurements .....	94
7.2.2	Cutting and Feeding Forces Measurements .....	94
7.2.3	Flank Wear Length Measurement .....	95
7.3	Result and Discussion.....	95
7.3.1	Average Surface Roughness .....	95
7.3.2	Cutting and Feeding Forces .....	97
7.3.3	Flank Wear Length .....	98
7.4	Conclusion .....	99

References

---

## PART III: IMPROVED PERFORMANCE OF HIGH SPEED CUTTING

---

### Chapter Eight – Coating For High Speed Cutting Tools

Suryanto  
 Kulliyyah of Engineering, International Islamic University Malaysia  
 ✉ : surya@iium.edu.my

8.1	Introduction .....	103
8.2	Cutting Tool – Workpiece Interaction .....	104
8.3	Important Properties of Coating .....	106
8.4	Type of coatings .....	108
8.4.1	Single layer single component coatings .....	108
8.4.1.1	Nitride Coating .....	108
8.4.1.2	Carbide Coatings.....	112
8.4.1.3	Boride coatings .....	114



8.4.1.4 Oxide coatings .....	115
8.4.1.5 Diamond coatings .....	116
8.4.1.6 Diamond-like Coatings .....	118
8.4.2 Single Layer Multicomponent coatings .....	120
8. 4.2.1. Single Layer - Gradient Coatings .....	121
8. 4.3. Multilayer coatings .....	121
8.5 Conclusion .....	122

## References

## Chapter Nine – Development of Tooling Cost Model in High Speed Hard Turning

Muataz Al Hazza<sup>1</sup> and Erry Yulian Triblas Adesta<sup>2</sup>  
 1, 2. Faculty of Engineering – International Islamic University Malaysia  
 ✉ : mutaz\_hazaa@yahoo.com /✉ : eadesta@iium.edu.my

---

9.1 Introduction.....	125
9.2 Cost Drivers .....	126
9.3 The Depth and Completeness of Cost Estimation Models .....	126
9.4 High Speed Hard Turning .....	129
9.5 Research Methodology .....	129
9.5.1 Materials.....	120
9.5.2 Experimental Design .....	131
9.5.3 Tool Life Measurement .....	132
9.6 Development of Tooling Cost Model .....	133
9.7 Discussion .....	137
9.8 Validation .....	138
9.9 Conclusion .....	139

## References

**Chapter Ten – Development of New Model for Cutting Force in High Speed Hard Turning**

Muataz Al Hazza<sup>1</sup> and Erry Yulian Triblas Adesta<sup>2</sup>  
1, 2. Faculty of Engineering – International Islamic University Malaysia  
✉ : mutaz\_hazaa@yahoo.com /✉ : eadesta@iium.edu.my

---

10.1 Introduction..... 145

10.2 Research Methodology ..... 146

10.3 Materials ..... 147

10.4 Experimental Setup..... 148

10.5 Results..... 149

10.6 Conclusion ..... 151

References

# **New Tool Life Models in Turning Hardened Steel AISI 4340 under High Cutting Speed**

Erry Yulian Triblas Adesta<sup>1</sup> and Muataz Al Hazza<sup>2</sup>

1, 2. Faculty of Engineering – International Islamic University Malaysia

✉ : eadesta@iium.edu.my / ✉ : mutaz\_hazaa@yahoo.com

---

## **1.1 Introduction**

The famous formula and its extensions for estimating and predicting the tool life has been established around one hundred years ago (1907) by Taylor and still used until now.

In 1977 the International Standard Organization introduced the standard ISO 3865 to unify tool life testing procedures. The standard defines tool life as the time elapsed until a defined amount of wear has occurred in the rake face or flank face of the cutting tool. More ISO standards followed to cover tool life testing procedures in face milling (ISO 8688-1, 1989) and end milling (ISO 8688-2, 1989) in addition to the revised version of ISO 3865 appeared in 1993. The purpose of these standards is to unify testing procedures in order to increase the reliability and the unity of test results when making comparisons of cutting tools, work materials, cutting parameters or cutting fluids.

Mehrban et al., (2007) claimed that Taylor equations consume a lot of time and money. Jawahir et al., (2003) said that it requires vast amounts of data and long experimental testing. Thus, establishing new models are utmost important.

Many researchers developed mathematical models for predicting the flank wear then the tool life for different cutting tools (Usui et al. 1984; Huang and Liang, 2004; Adesta et al., 2009; Singh & Rao, 2010)

In high speed cutting for hard materials, the cutting area is under high temperature, high pressure, and high sliding velocity. Therefore, the cutting tool under this condition has normally complex wear behaviors. Mamalis et al., (2002) claimed that with the change of cutting conditions, the tool's mechanical and thermal load changes, and the ratio of the wear components modifies. Therefore, it is difficult to handle mathematically.